O 63: Plasmonics and Nanooptics V

Time: Thursday 10:30–13:00 Location: H32

O 63.1 Thu 10:30 H32

Enhancing higher harmonics generation using plasmonic nanostructures — •Thomas Paul, Christoph Menzel, Carsten Rockstuhl, Shakeeb Bin Hasan, and Falk Lederer — Institute of Solid State Physics and Optics, Friedrich Schiller Universität Jena, Germany

Exploiting the properties of plasmon polaritons sustained by metallic nanostructures opens up great opportunities in engineering linear and nonlinear optical properties of conventional optical matter. Whereas the linear properties are usually at the focus of interest, also the nonlinear properties may benefit. If the metallic nanostructures are operated in resonance, the enhanced electrical field concentration facilitates the nonlinear interaction of light with matter. In our work we aim to detail such processes from a theoretical point of view. Particularly, we investigate the potential to enhance the higher harmonics generation by periodically arranged metallic nanostructures incorporated into a (nonlinear) dielectric host material. The geometries we are interested in are pairs of gold nanowires and split cylinder resonator structures. Emphasis is put on $\chi(2)$-nonlinearities for which it is reasonably assumed that the intrinsic nonlinearities of the dielectric host material prevails against those of the metallic nanostructures. Independent of the structure, we reveal the peculiarities of how the various types of resonances (dipolar or quadrupolar) may boost the conversion efficiency of the fundamental light into its higher harmonics (i.e. second harmonic). Possible implications to use the process of parametrical amplification for compensating absorption losses will be discussed.

O 63.2 Thu 10:45 H32

Theoretical Investigation of the Electron Emission from Metal Nanotips — •Steve Lenk and Erich Runge — Institut für Physik und Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, 98693 Ilmenau, Germany

We investigate the electron emission process from sharp metallic nanotips illuminated by low-power femtosecond laser pulses theoretically. The emission processes under discussion for few-femtosecond laser pulses are multiphoton emission [1] and optical field emission [2]. We calculate the probability current from a numerical solution of an initial value problem [3] via an exponential split-operator method and a real space product formula algorithm [4] in one and two spatial dimensions. The time-dependent electric potential used for the study of the electron emission is derived from the charge distribution on the tip apex. The electric field and the photoelectron current are compared with experimental results.

[1] C. Ropers, D. Solli, C. Schulz, C. Lienau, and T. Elsaesser, Phys. Rev. Lett. **98**, 043907 (2007).

[2] P. Hommelhoff, C. Kealhofer, and M. Kasevich, Phys. Rev. Lett. **97**, 247402 (2006).

[3] S. Glutsch, *Excitons in Low−Dimensional Semiconductors*, Springer Heidelberg (2004).

[4] H. De Raedt, Comp. Phys. Rep. **7**, 1 (1987).

O 63.3 Thu 11:00 H32

Electromagnetic field enhancement at nanostructured surfaces — •Natalia Garcia Rey and Heike Arnolds — Surface Science Research Centre, University of Liverpool, Oxford Street, Liverpool L69 3BX, UK

Metal surfaces with nanometer scale roughness have been found to be photochemically more active than flat surfaces. This is believed to be caused by the excitation of surface plasmons, which create enhanced electromagnetic fields at the surface.

In this contribution, we explore the field enhancement obtainable from sub-wavelength periodic ripple structures created by argon ion sputtering in UHV, where we model the ripple surface structure as quasi-sinusoidal and solve Maxwell's equations in 2D with the help of finite-element modelling. We calculate the average surface field enhancement for various substrates (noble and transition metals) and vary incident wavelength and ripple periodicity and height.

Based on these results we discuss to which degree it is possible to maximize the electric field strengths and in turn the photochemical cross section using simple large-scale surface patterning techniques like sputtering.

O 63.4 Thu 11:15 H32

Optical response of metallic nanostructures: simulation vs. measurement — •Reto Giannini[1], Patrick Leidenberger[2], Christian Hafner[2], and Jörg F. Löffler[1] — [1]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich, 8093 Zurich, Switzerland — [2]Laboratory for Electromagnetic Fields and Microwave Electronics, ETH Zurich, 8092 Zurich, Switzerland

Today various different tools for calculating the optical response of metallic nanostructures are available. All of them are based on a geometric description of the nanostructures, which makes it difficult to take into account production-based variations in the shape of the structure under investigation. In the context of plasmon resonances in the optical wavelength range and related effects, such as field enhancement, this discrepancy can generate significant deviations between simulation and measurement. To address this problem, we performed a series of FEM-based simulations on Au-nanoparticles, aiming to approach as closely as possible the structures available using today's state-of-the art production techniques. The simulations were carried out using JCMsuite (axis-symmetric model) and Comsol (full 3D), and special attention was paid to corners, triple-points and particle deformation. The calculated results were then compared with nanoparticles produced and analyzed in-house.

O 63.5 Thu 11:30 H32

Modeling Metallic Nanostructures using a Discontinuous Galerkin Approach — •Jens Niegemann[1,2], Michael König[1,2], Richard Diehl[1], Christopher Prohm[1], and Kurt Busch[1,2] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Karlsruher Institut für Technologie

Over the past few years, the discontinuous Galerkin time-domain (DGTD) method has established itself as an extremely powerful and efficient numerical technique in the field of photonic. Due to its combination of an accurate spatial discretization with an explicit time-stepping scheme, the DGTD method is particularly well suited for studying ultra-short and/or plasmonic phenomena.

Here, we present our recent advances in using the DGTD method for the simulation of metallic nanostructures. In particular, we present the advantages of using higher-order curved elements. Furthermore, we will discuss some of our recent developments with respect to the improvement of the time integration.

O 63.6 Thu 11:45 H32

Mode Tuning in Microresonators Using Uniaxial Anisotropy and Resonator Shaping — •Stefan Declair, Cedrik Meier, Torsten Meier, and Jens Förstner — University of Paderborn, Department of Physics and CeOPP, Warburger Str. 100, D-33098 Paderborn, Germany

We numerically investigate resonant modes in microdisks and photonic crystal cavities. Mode tuning of the resonant modes, which is desirable for many applications, e.g. for achieving strong coupling, in a broad frequency range is shown using (a) uniaxial anisotropy of either the surrounding environment or the photonic structure and (b) in non-cylindrical microdisks. In both cases anticrossing behavior is observed when modes of different mode order approach each other. Additionally, we compare our simulations with experimental results from a 3 μm microdisk embedded in a liquid crystal environment.

O 63.7 Thu 12:00 H32

Microcavity Plasmonics — •Ralf Ameling and Harald Giessen — 4th Physics Institute, University of Stuttgart, Germany

We couple hybridized plasmon modes in cut-wire metamaterials with resonator modes of a microcavity. Depending on the position of the cut-wire pair in the resonator, the symmetric (electric) or antisymmetric (magnetic) plasmon mode is coupled, manifested by an anticrossing of the resonances. We explain this behavior by taking the symmetry and spatial distribution of the electric fields in the resonator into account. Experimental results verify the predicted mode-splitting due to the strong resonant coupling and agree well with theory. Our work can serve as a model system for far-field plasmon-plasmon coupling and paves the way towards enhanced plasmon-plasmon interaction in photonically coupled three-dimensional Bragg structures.

O 63.8 Thu 12:15 H32

Functional elements on subwavelength plasmonic waveguides — •Andreas Reiserer[1], Philip Tuchscherer[1], Christian Rewitz[1], Dmitri V. Voronine[1], Jer-Shing Huang[2], Bert Hecht[2], and Tobias Brixner[1] — [1]Institut für Physikalische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Nano-Optics and Biophotonics Group, Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Plasmonic functional elements are promising to combine the advantages of photonics and electronics – high speed and small spatial extent. We employ numerical simulations and an analytic approach based on transmission line theory to demonstrate several functional elements that consist of so called stub structures – terminated ends on metal–insulator–metal waveguides.

Splitters are presented that allow arbitrary adjustment of the transmission ratio from an input to two different output arms; frequency filters are designed that provide steep transmission resonances; and, finally, nanoscale all-plasmonic switching is proposed with an operating frequency of more than 20 THz.

The suggested device components are promising for future applications in ultrafast nanoscale information processing.

O 63.9 Thu 12:30 H32

Optimally Shaped Laser Pulses for Hybrid Metal-Semiconductor Nanostructures — •Matthias Reichelt[1], Torsten Meier[1], Andrea Walther[2], and Michael Dellnitz[2] — [1]Department Physik, Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany — [2]Institut für Mathematik, Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

A hybrid nanostructure which consists of a metal aperture and a semiconductor quantum wire is studied theoretically. [1] It is shown that one can concentrate the optically excited electron density at an arbitray position for a given time using sophistically shaped laser pulses. To obtain the optimized laser field a genetic algorithm [2] and a more rigorous mathematical approach [3] are applied. Full three-dimensional finite-difference time-domain calculations [4] confirm the predicted spatiotemporal control.

[1] M. Reichelt and T. Meier, Opt. Lett. **34**, 2900 (2009).

[2] A.E. Eiben and J.E. Smith, *Introduction to Evolutionary Computing*, Springer (2003)

[3] S. Sertl and M. Dellnitz, Journal of Global Optimization **34**, 569-587, (2006).

[4] A. Taflove, *Advances in Computational Electrodynamics*, Artech House, (1998).

O 63.10 Thu 12:45 H32

Analytic Theory of Linear Plasmonic Antennas — Jens Dorfmüller[1], Ralf Vogelgesang[1], •Moritz Esslinger[1], Worawut Khunsin[1], Christian Ettrich[2], Carsten Rockstuhl[2], and Klaus Kern[1] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Institute of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller Universität Jena

At radio-frequencies, antenna theory is a well understood topic. At optical frequencies, however, antenna sizes are in the order of skin depths so that electromagnetic fields penetrate substantially into the volume of metallic nanostructures, rendering classic radio antenna theory not applicable. We develop a fully analytical model for the electromagnetic behavior of plasmonic wires. Therefore, we model thin, linear plasmonic antennas based on the assumption of homogeneous volume currents. Our model requires only a handful, physically motivated, adjustable parameters. It successfully predicts measured and simulated data in full detail: emission patterns, nearfield optical amplitudes and phases, as well geometric resonances.